Liquid-Wall Temperature Limits

Based on core impurity contamination

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Outline

1. **Lithium results**

    - lower edge densities
    - self-shielding effect
    - thermal collapse

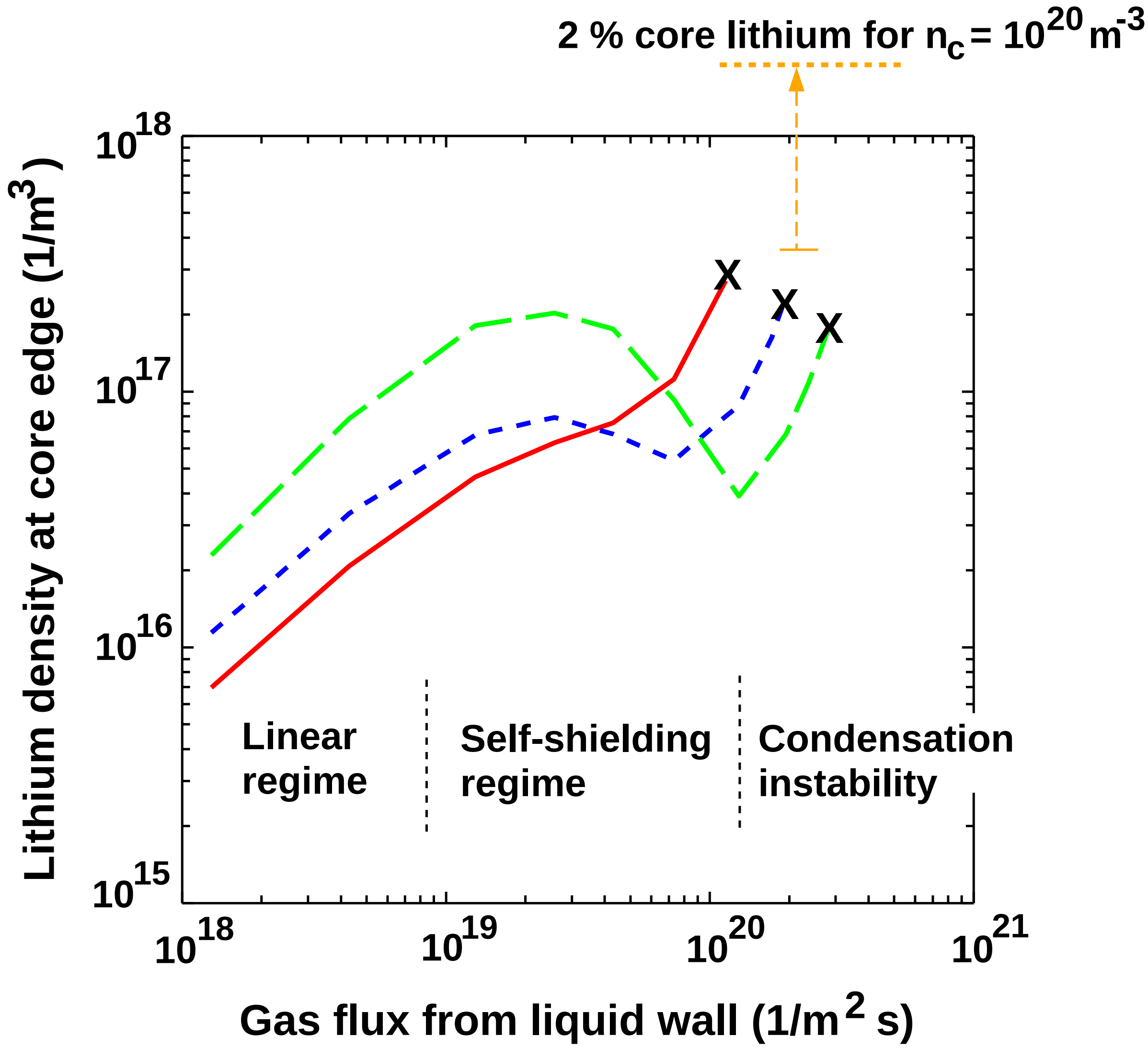
2. **Flibe results**

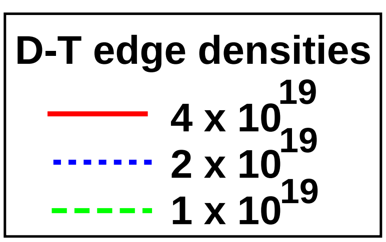
    - differences from Lithium
    - low- and high-recycling regimes

3. **Auxiliary heating and localized evaporation region**

4. **Summary and plans**

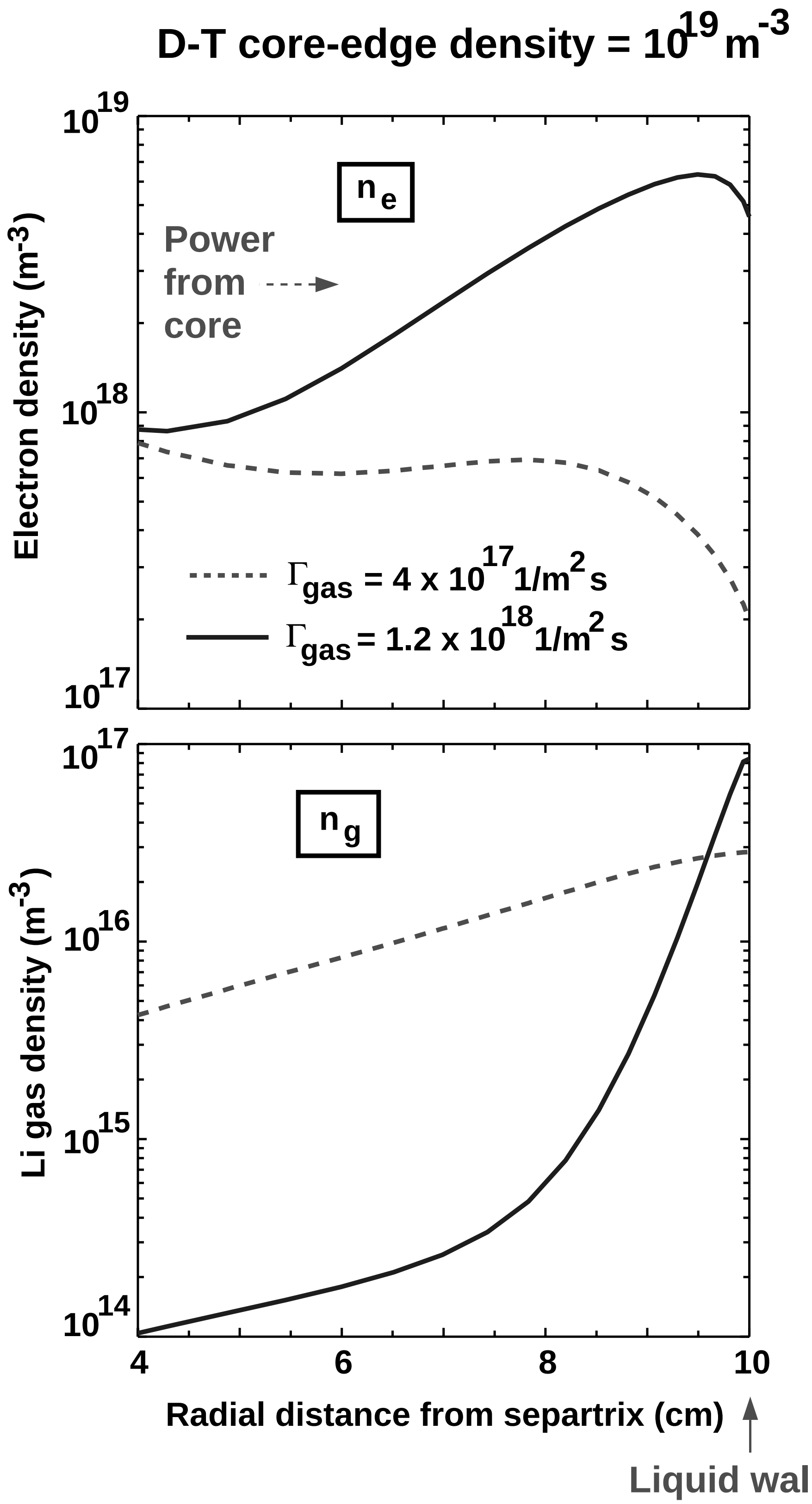
Impurity intrusion has three regimes for Li





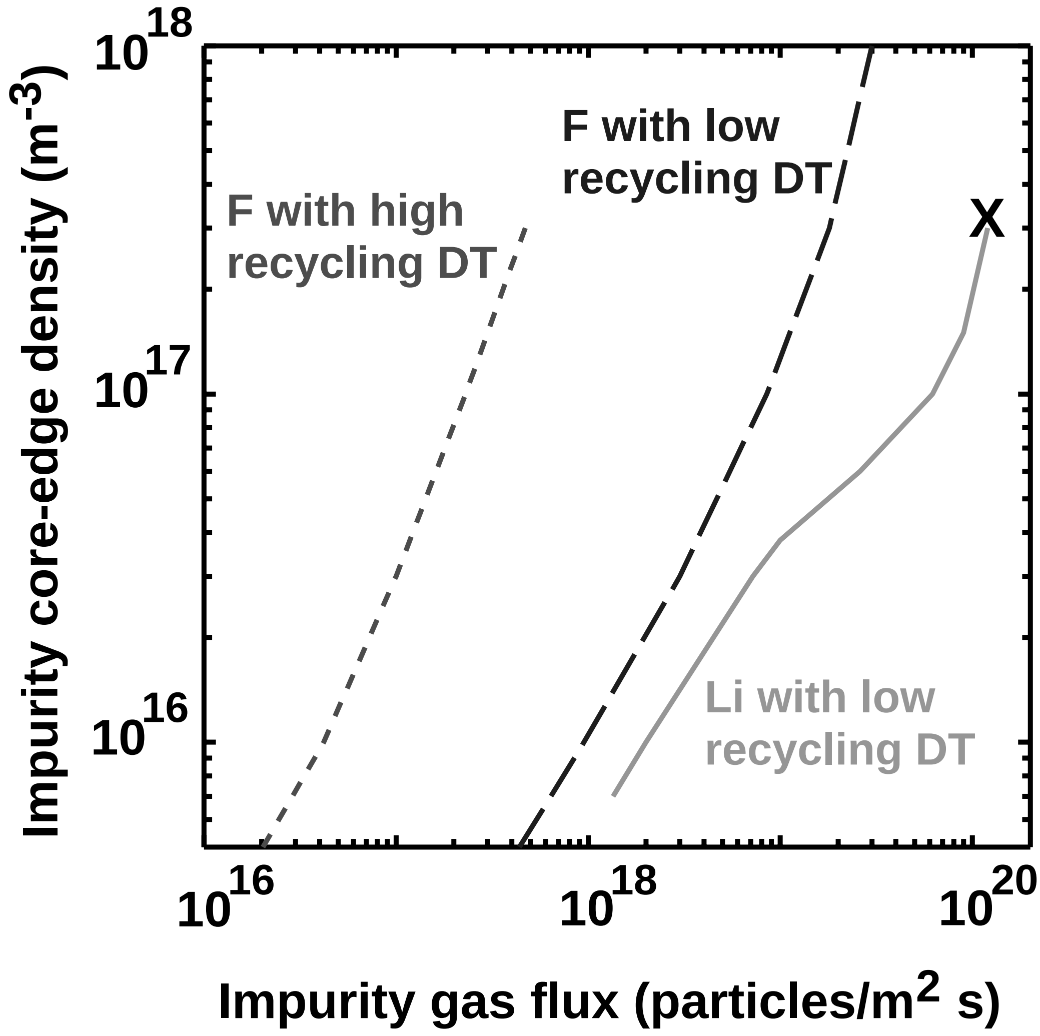
Simple plate sputtering model with yield of 0.4 adds <4 x 10^{16} m^{-3} to the Li core edge density

Dense Li plasma can form to shield core



Fewer impurity ions from Li vapor penetrate to the core than for F vapor

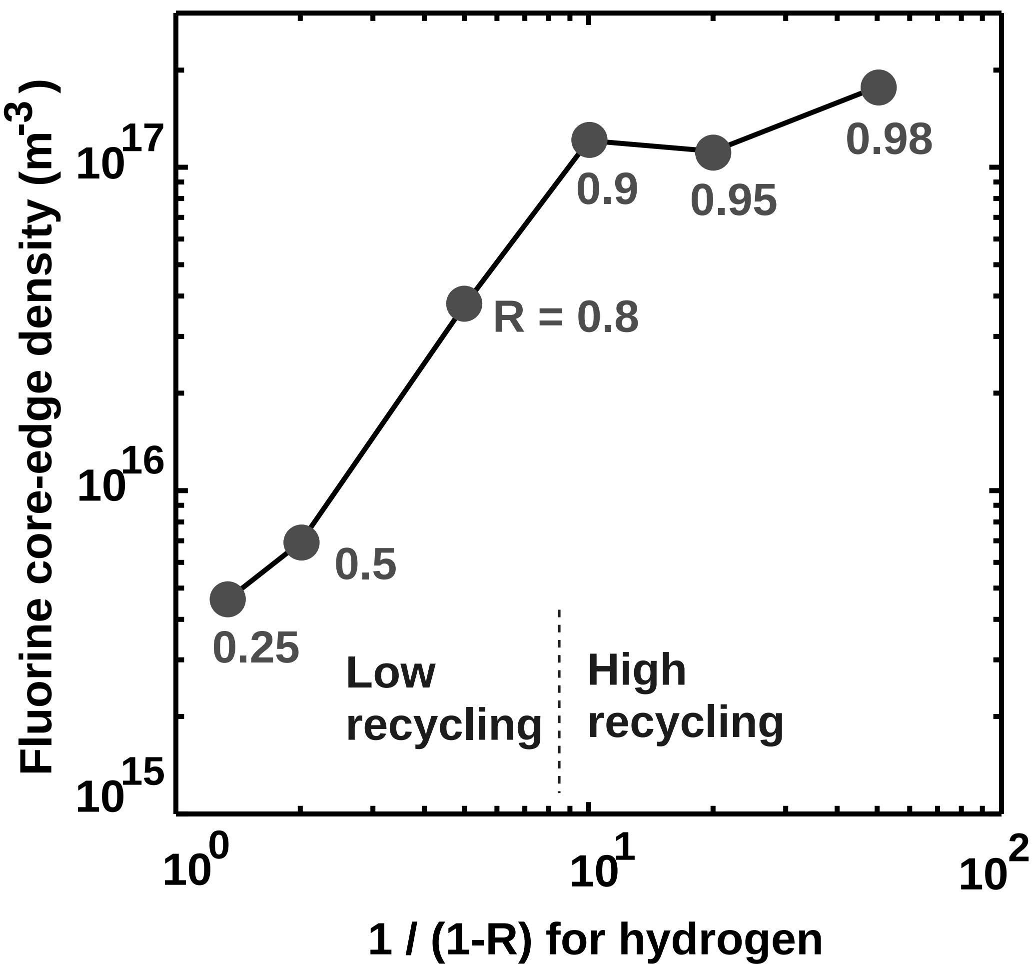
- Cases correspond to standard tokamak configuration
- X denotes onset of radiation/condensation instability
- F comes from assumed Flibe wall; Li from Li or SnLi



Fluorine core density varies a factor of ~50 from low to high hydrogen recycling, R

Effective hydrogen particle lifetime is 1 / (1-R), so divertor density rougly scales with it

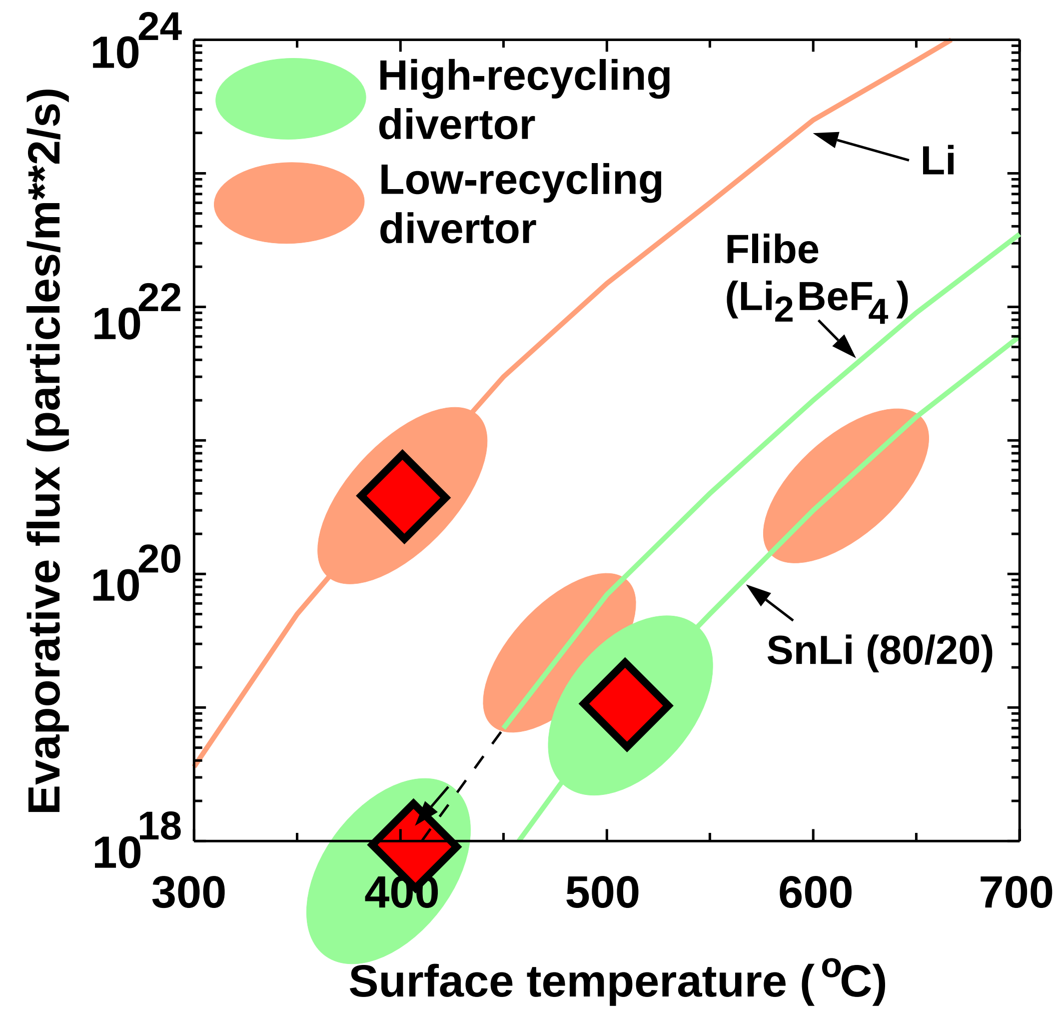
Wall fluorine gas-flux = 4.3×10^{17} 1/s



Side-wall impurity influx sets <u>tokamak</u> liquid temperature limits

Impurity transport in edge region from 2-D UEDGE code

◆ shows cases with same wall/divertor material, and no auxillary heating methods



Details for Flibe temperature limits based on core impurity penetration

Conclusions from simulations to date:
(for close-fitting wall ~10 cm from separatrix)

- **For high recycling (R > 0.9), <u>tokamak</u> Flibe wall limit is below 450 C**

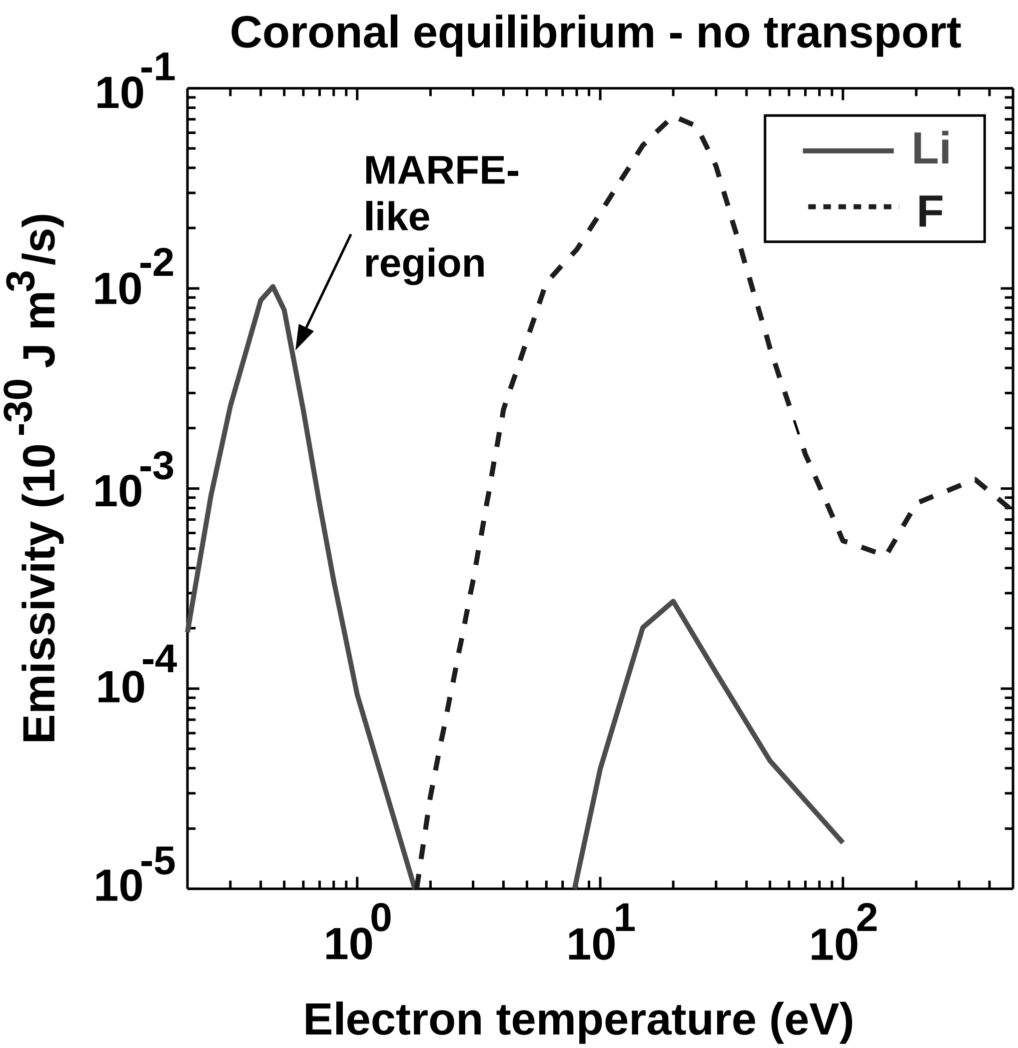
- **For low recycling (R < 0.5) and successful auxiliary heating, the <u>tokamak</u> Flibe wall limit is at best 500 C**

Further work for reduced core impurities from Flibe wall:

- **Improve intervention techniques**
  - move wall farther from core with auxiliary heating
  - use injection deutrium stream to sweep vapor out
  - new inovation

- **Analyze other configurations with natural low recycling edge-plasmas, e.g., the FRC**

Emissivity shows low Te peak for Li



Radiated power = Emissivity x n_e x n_{imp}

Auxiliary heating can be roughly constrained by power considerations

UEDGE calculations show energy cost per neutral

- **for lithium, 200-300 eV**
- **for fluorine, 2000-3000 eV**
- **these high values come from ionizing to upper charge states near the core boundary**

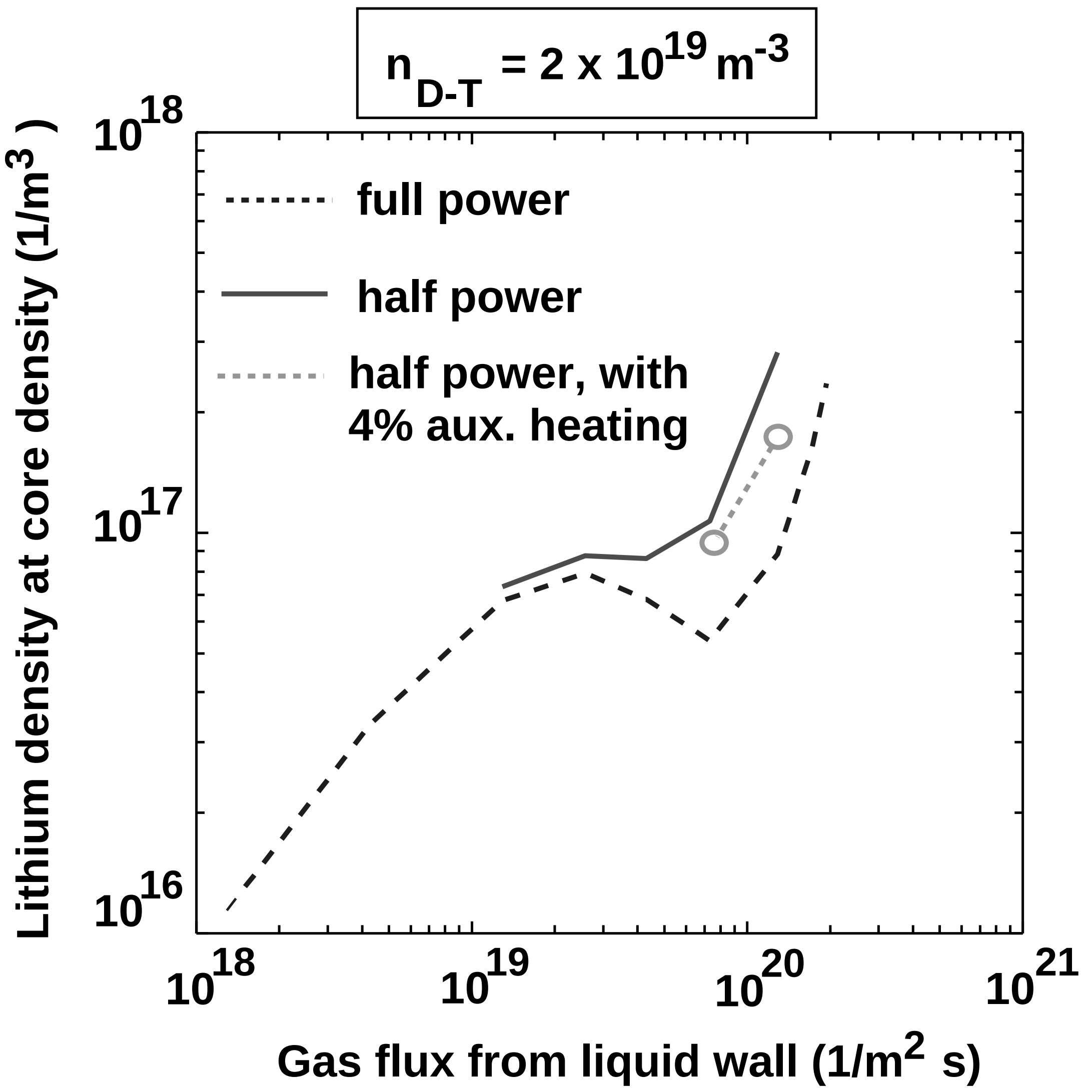
-- For an ITER-size device, assuming gas flux of 10^{20}/ m^2 s with area of 1000 m^2 yields

- **for lithium, power is ~4 MW**
- **for fluorine, power is ~40 MW**

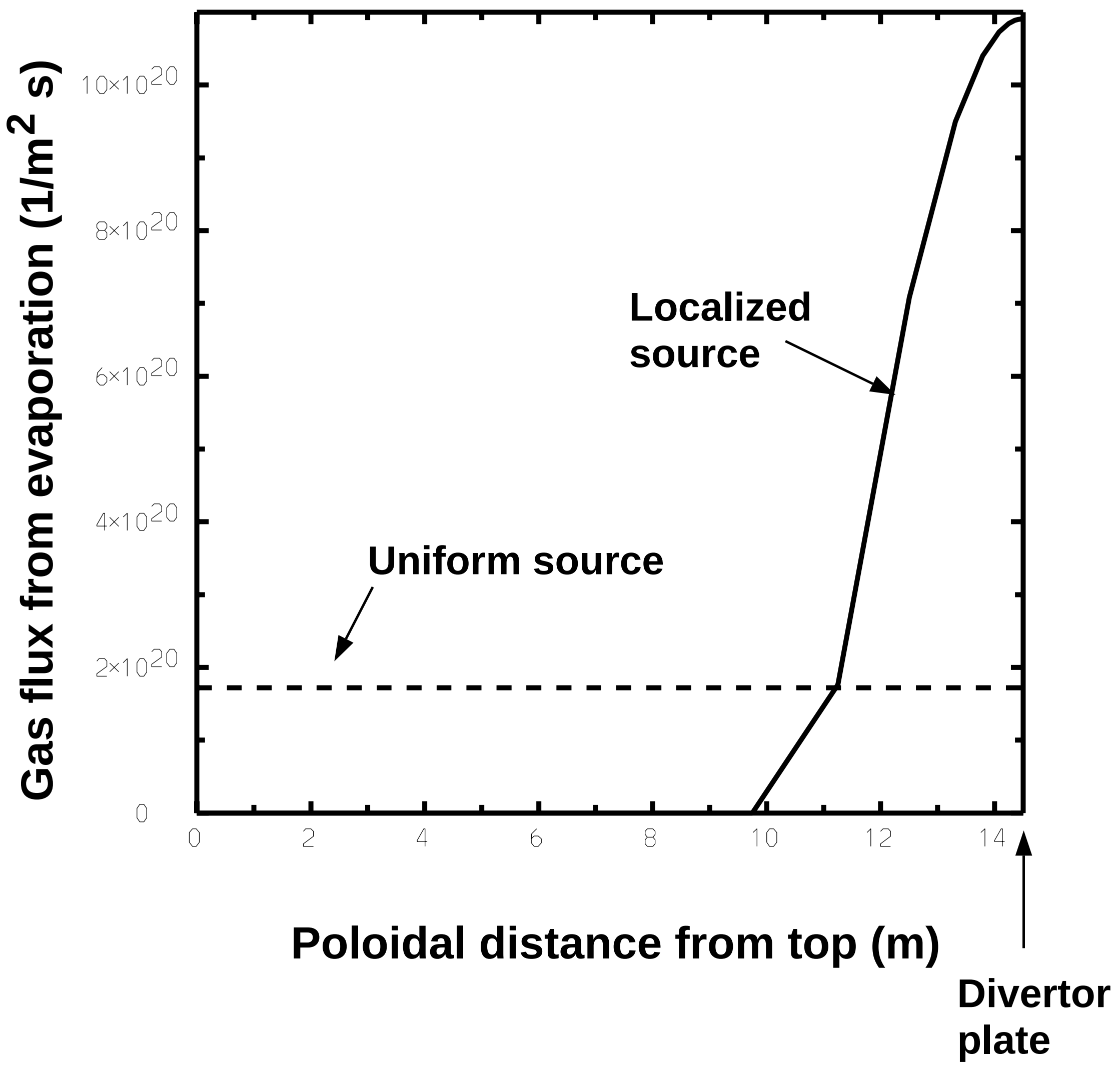
-- Up buttons

- **smaller, higher power density devices**
- **separating vapor plasma from edge plasma**

Reducing core power decreases shielding; auxiliary heating can help as replacement

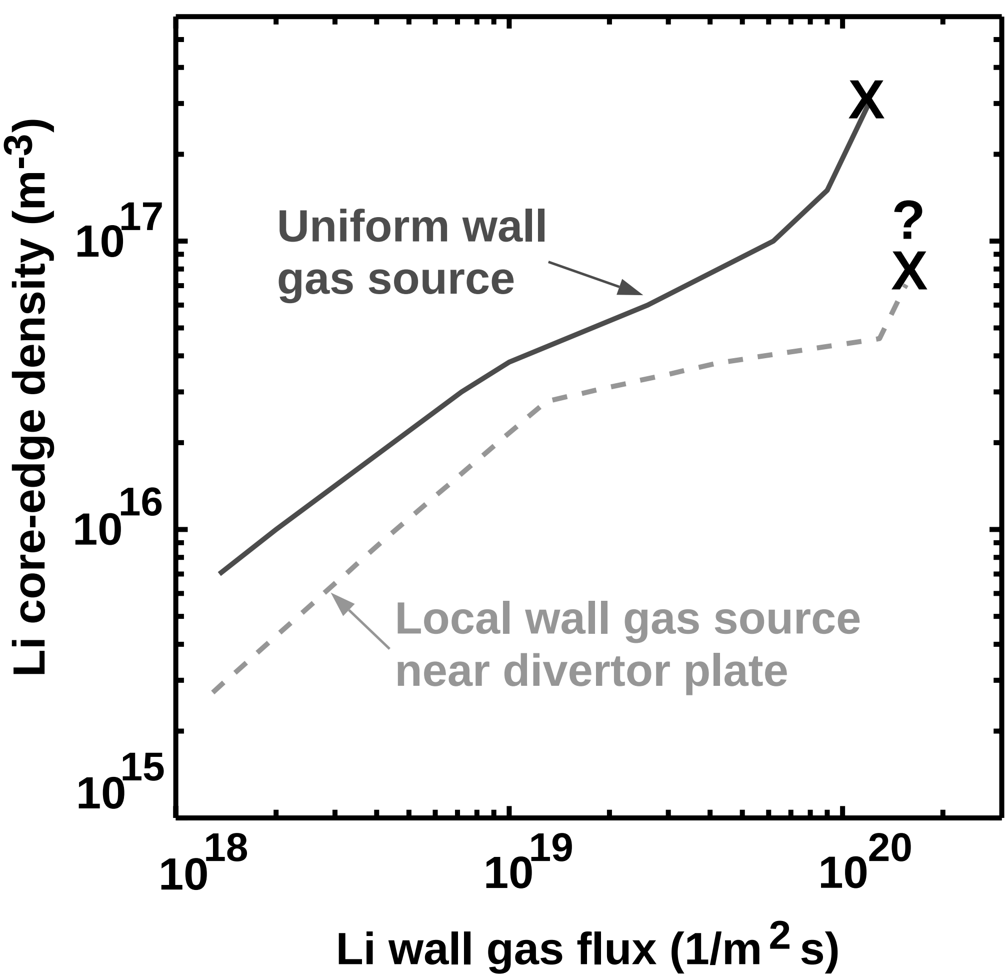


Gas wall source profiles for two extremes



Localized evaporation source lowers impurity influx; rad. instability still limits

- Standard lithium low-recycling case
- X denotes radiation/condensation instability



Summary of impurity modeling with UEDGE

Divertor impurity sources

- Completed first UEDGE/WBC coupling for Li sputtering which shows low Li core concentration - see Brooks

Wall impurity sources

- Low hydrogen-recycling plasmas can tolerate higher evaporative impurity flux than high recycling plasmas
- Lithium is better shielded from the core plasma than fluorine
- For tokamaks without auxillary removal methods, an all Flibe wall/divertor likely will have excessive core impurities; others devices should be better (e.g., FRC)
- Auxillary heating of edge plasma can significantly reduce impurity influx
- For low-density, low-recycling edge-plasmas, self shielding by impurity plasma helps limit core impurities

Plans

- Assess auxiliary heating and larger wall/separatrix gap
- Improve model: kinetic effects, more coupling to WBC
- Analyze different configurations (e.g., FRC, spheromak)
- Compare with experiments - TFTR, DIII-D, CDX-U